ECE 145A / 218A

J.R
11/2/18

Problem Set # 3 Solutions

Problem #1

From smith chart $\rightarrow$ $z_{in} = 3.423 + j0$ $\Rightarrow Z_{in} = 171.15\Omega$

$$@ \frac{\lambda}{4} \Rightarrow Z_{in} = \frac{Z_0^2}{Z_L} \Rightarrow \boxed{Z_0} = \sqrt{Z_{in} \cdot Z_L} = \boxed{92.5\Omega}$$

$$\text{Poles } @ f_1 = 105\text{ GHz} = \frac{1}{4\tau_1} \Rightarrow \tau_1 = 2.38\text{ps} \Rightarrow \boxed{V = \frac{l}{\tau_1} = 2.1 \times 10^8 \frac{m}{s}}$$

Problem #2

$W_{max} < \lambda d/2$

$$a.)\ \lambda d = \lambda_0/\sqrt{\varepsilon_r} = \frac{c}{f\sqrt{\varepsilon_r}} = \frac{3\times 10^8 \text{ m/s}}{300\text{ GHz}\cdot\sqrt{12.7}} = 609\mu m$$

$$\Rightarrow \boxed{W_{max} \cong 304.3\mu m}$$

DC : $Z_{in} = \infty$
$\lambda d/4$: $Z_{in} = 0$
$\lambda d/2$: $Z_{in} = \infty$

$\Big\}$ Z_{in} goes to ∞ at $L_{max} = \frac{\lambda d}{2}$ $\Rightarrow \boxed{L_{max} = 304.3\ \mu m}$

$$C = \frac{\varepsilon A}{H} = \frac{\varepsilon_0 \cdot \varepsilon_r \cdot W_{max} \cdot L_{max}}{\underset{\searrow 6\mu m}{H}} = 0.369\text{ pF}$$

c.) 

$A = \frac{\pi r^2}{4}$ where $\varepsilon_r \rightarrow \varepsilon_{eff} \approx \frac{\varepsilon_r + 1}{2} = 1.85$

$$L_{max} = \frac{\lambda d}{2} = \frac{c}{2f\cdot\sqrt{\varepsilon_{eff}}} = \boxed{367.6\mu m}$$

$$C = \frac{\varepsilon_r \cdot \varepsilon_0 \cdot \pi L^2}{4H} = \boxed{0.423\text{ pF}}$$

$$\boxed{C_{radial} > C_{line} \qquad L_{max,\ radial} > L_{max,\ line}}$$

Problem 3

5 μm wide

@λ/4

2.) From Smith chart $\Rightarrow z = 3.412 + j0 \Rightarrow Z_{in} = 170.6\,\Omega$

$\Rightarrow \boxed{Z_{High}} = \sqrt{Z_{in} \cdot Z_L} = \boxed{92.36\,\Omega}$

$\hookrightarrow$ 50Ω

constant for all other lines because it is measured from an open line, and is only dependent on substrate...

81 μm

@ $f = 653$ GHz $= \frac{1}{4\tau} \Rightarrow \tau = 0.383$ ps $\Rightarrow \boxed{V = \frac{l}{\tau} = 2.11 \times 10^8 \frac{m}{s}}$

50 μm Wide

From Smith chart $\Rightarrow z = 0.185 + j0 \Rightarrow Z_{in} = 9.25\,\Omega$

$\Rightarrow \boxed{Z_{low}} = \sqrt{Z_{in} \cdot Z_L} = \boxed{21.5\,\Omega}$

Input:

$\tau_{High} = \frac{l_{High}}{V} = 0.383$ ps $\qquad \tau_{low} = \frac{l_{low}}{V} = \frac{296.04\,\mu m}{2.11 \times 10^8 \frac{m}{s}} = 1.4$ ps

$\Rightarrow$ ignore C $\qquad \Rightarrow$ ignore L

$\Rightarrow L_{High} = \tau_{High} \cdot Z_{High} = 35.4$ pH $\qquad \Rightarrow C_{low} = \tau_{low}/Z_{low} = 65.1$ fF

Output:

$\tau_{High} = \frac{452\,\mu m}{V} = 2.14$ ps $\qquad \tau_{low} = \frac{436.61\,\mu m}{V} = 2.07$ ps

$L_{High} = 0.198$ nH $\qquad C_{low} = 96.3$ fF

~~100GHz~~

smith chart

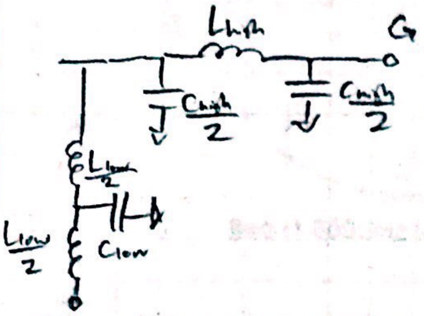
Problem 7: Want : $Z_{line} = 75\,\Omega \Rightarrow Z_{in} = \frac{Z_{line}^2}{Z_L} = 112.5 \Rightarrow z = 2.25 + j0$

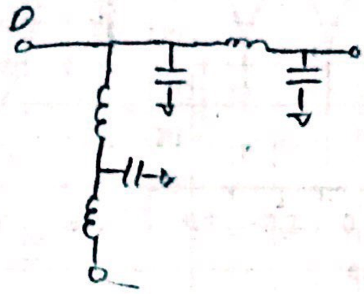
From tuning to find $z = 2.25 + j0 \Rightarrow W = 7.81\,\mu m$ Series

Repeat for $Z_{line} = 25\,\Omega \Rightarrow z = 0.25 + j0 \Rightarrow W = 41.54\,\mu m$, Shunt.

Problem 8

a)





$Z_{High} = 75\,\Omega$, $Z_{Low} = 25\,\Omega$ $\qquad V = C/\sqrt{\varepsilon_r} = 1.82 \times 10^8 \frac{m}{s}$ (ε_r: 2.7)

__Input:__

$\tau_{High} = \frac{l_{high}}{V} = \frac{89.5\,\mu m}{V} = 0.492\,ps \Rightarrow L_{high} = \tau_{high} \cdot Z_{high} = 36.9\,pH$, $C_{high} = \tau_{high}/Z_{high} = 6.56\,fF$

$\tau_{Low} = \frac{l_{low}}{V} = \frac{333.5\,\mu m}{V} = 1.83\,ps \Rightarrow C_{low} = \tau_{low}/Z_{low} = 73.2\,fF$

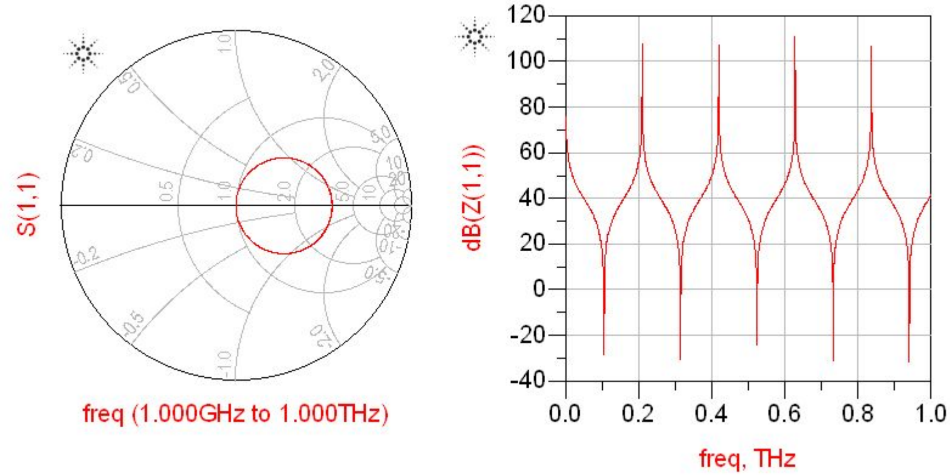
$L_{low} = \tau_{low} \cdot Z_{low} = 45.75\,pH$

__Output:__

$\tau_{High} = \frac{135\,\mu m}{V} = 0.742\,ps \Rightarrow L_{High} = 55.6\,pH$, $C_{high} = 9.89\,fF$

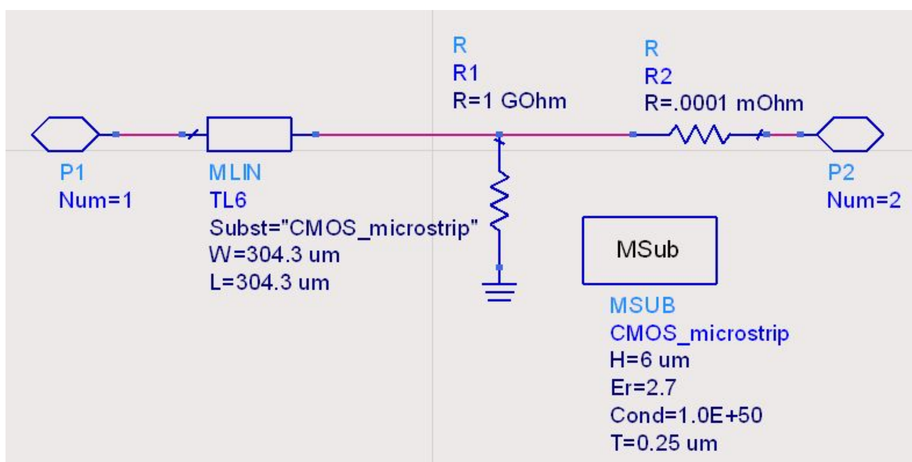
$\tau_{Low} = \frac{39\,\mu m}{V} = 0.214\,ps \Rightarrow C_{low} = 8.56\,fF$, $L_{low} = 5.35\,pH$

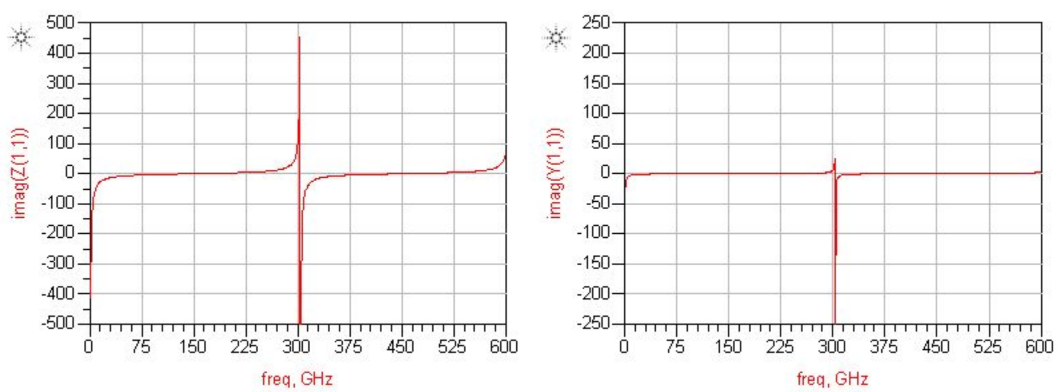
Problem 1



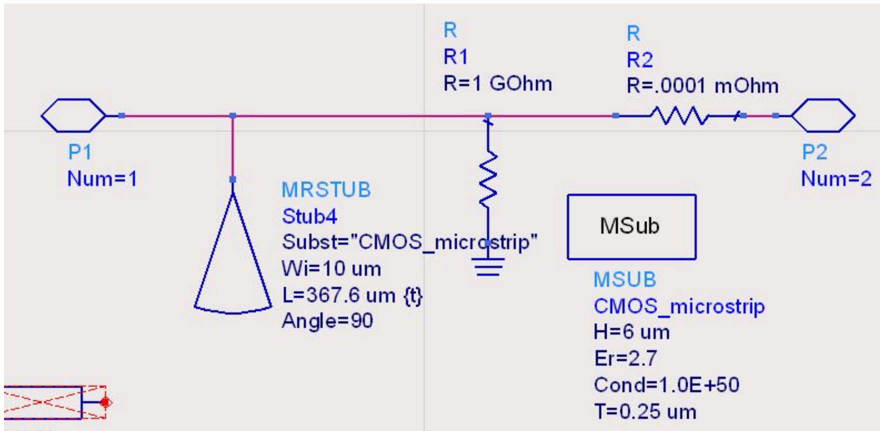
Problem 2

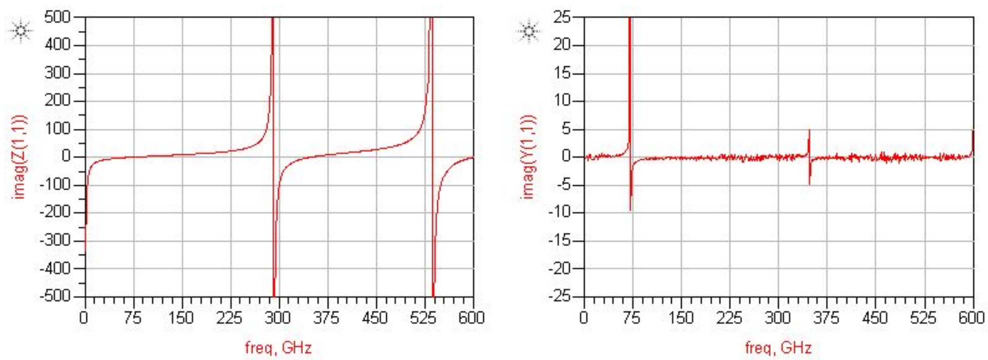
Part B





Part D

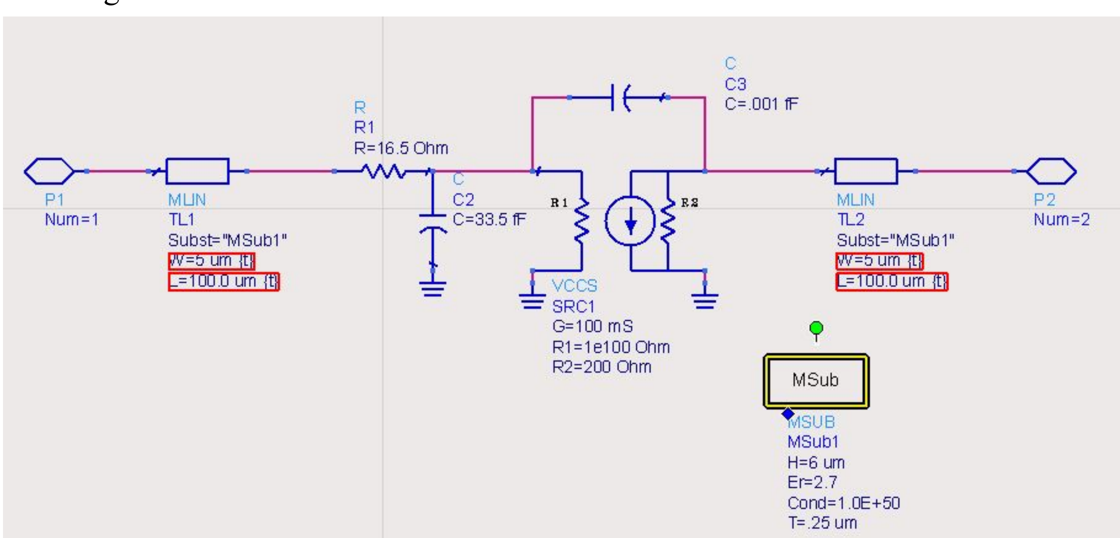


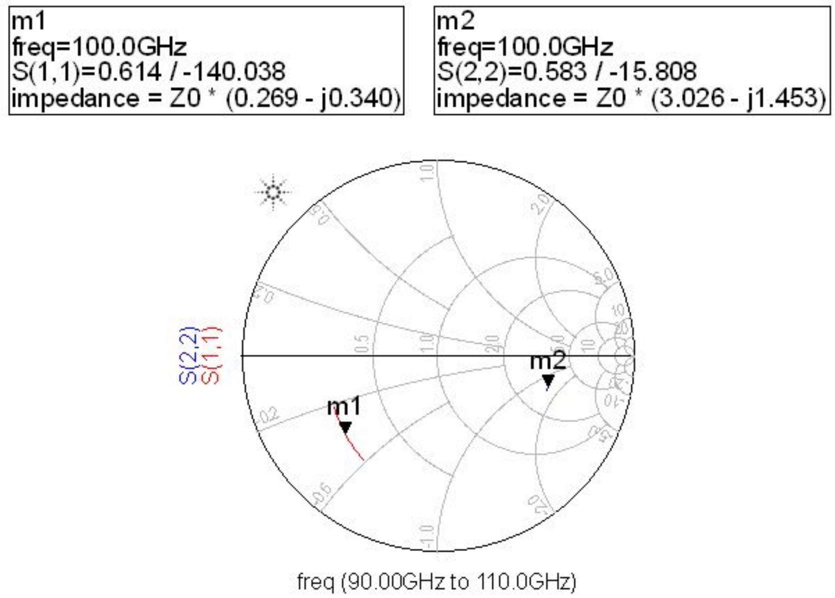


Problem 3

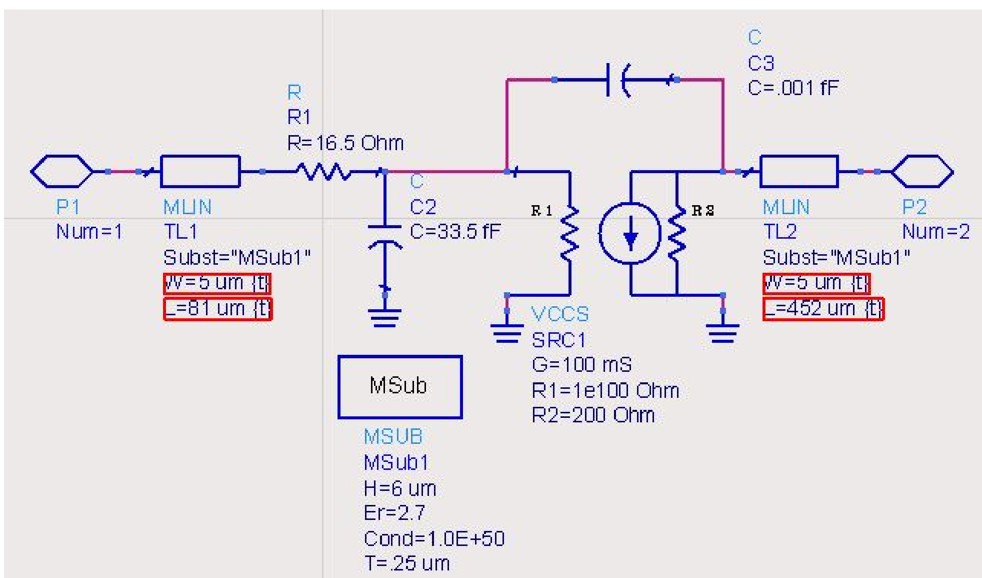
Part A

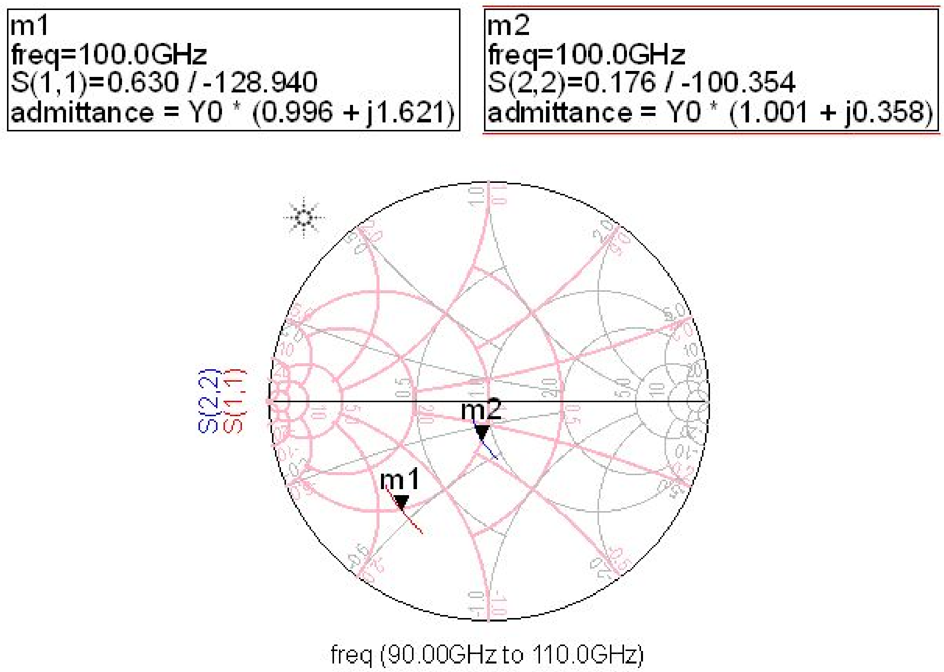
Before tuning:



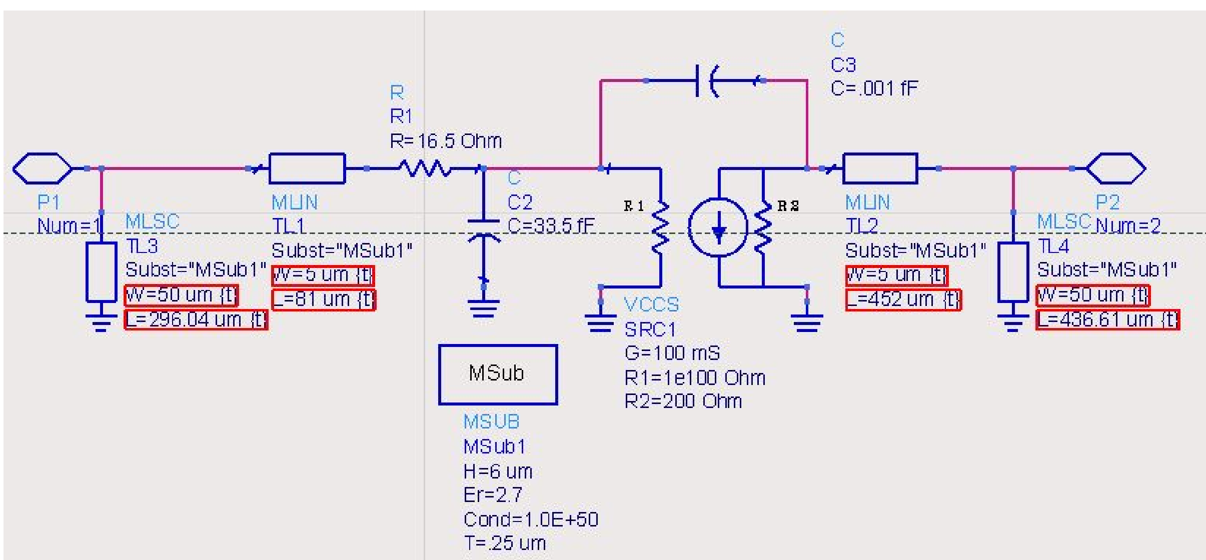


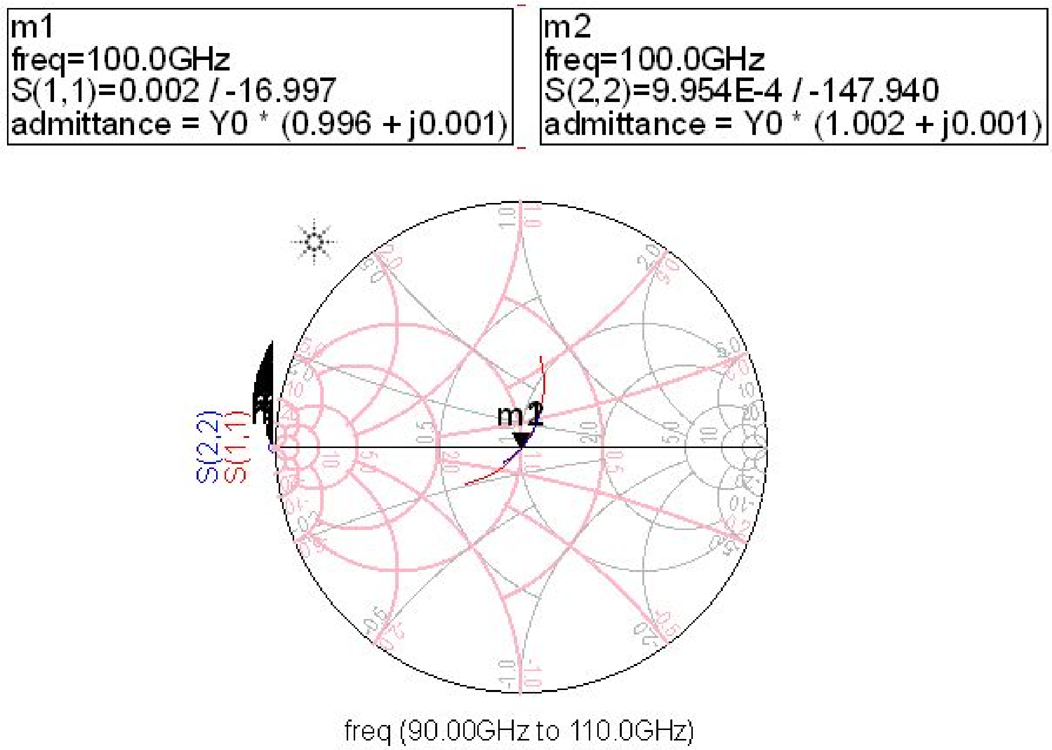
High-Impedance 5 um-wide line:
Tune to constant conductance:





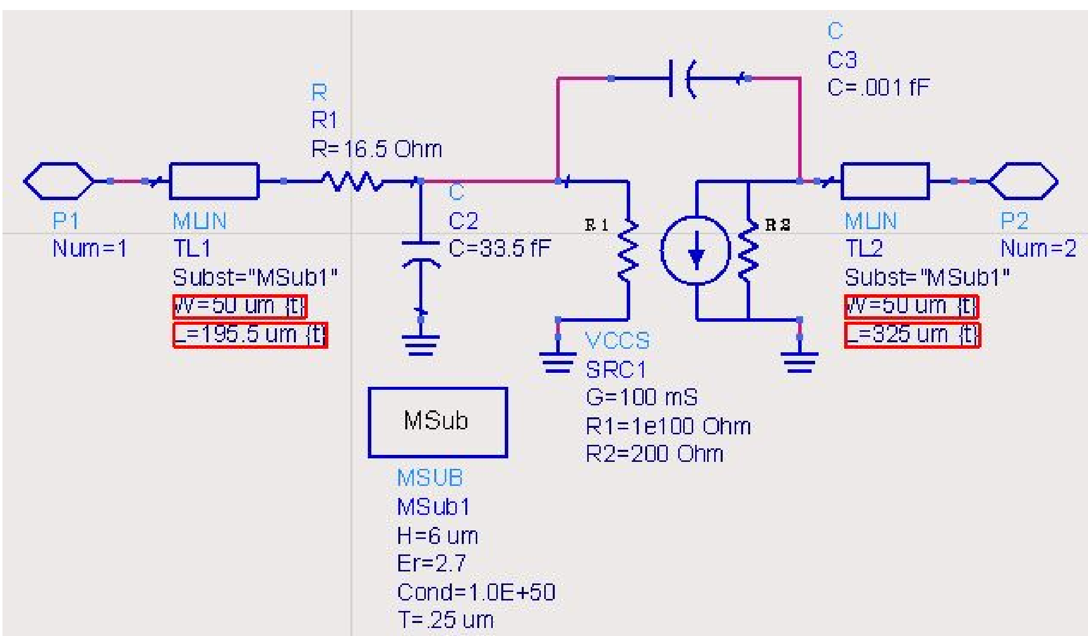
Adding shunt inductance to move along constant circle of conductance:

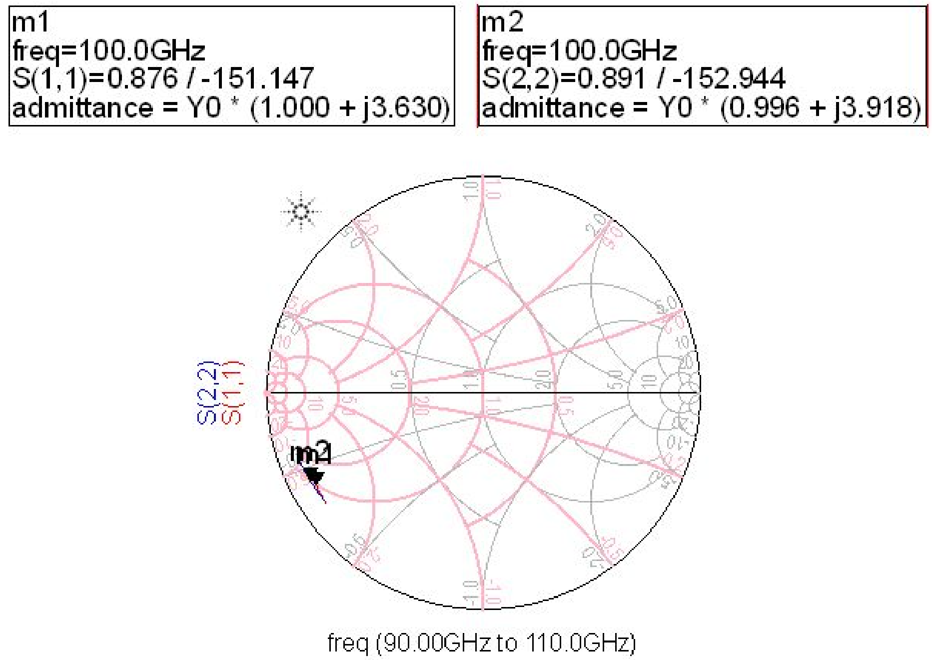




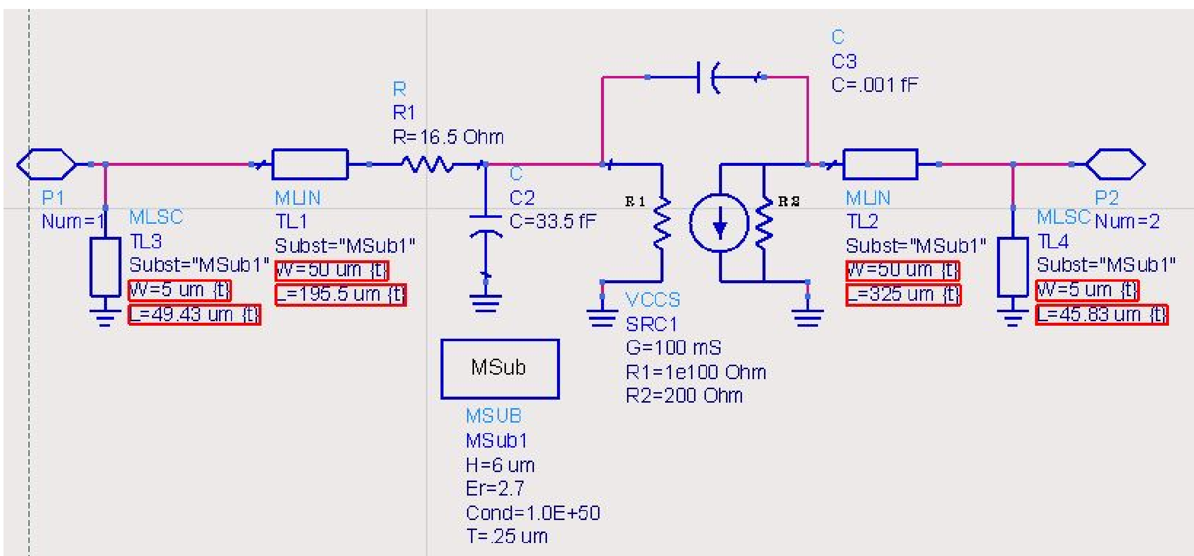
Low-Impedance 50 um-wide line:

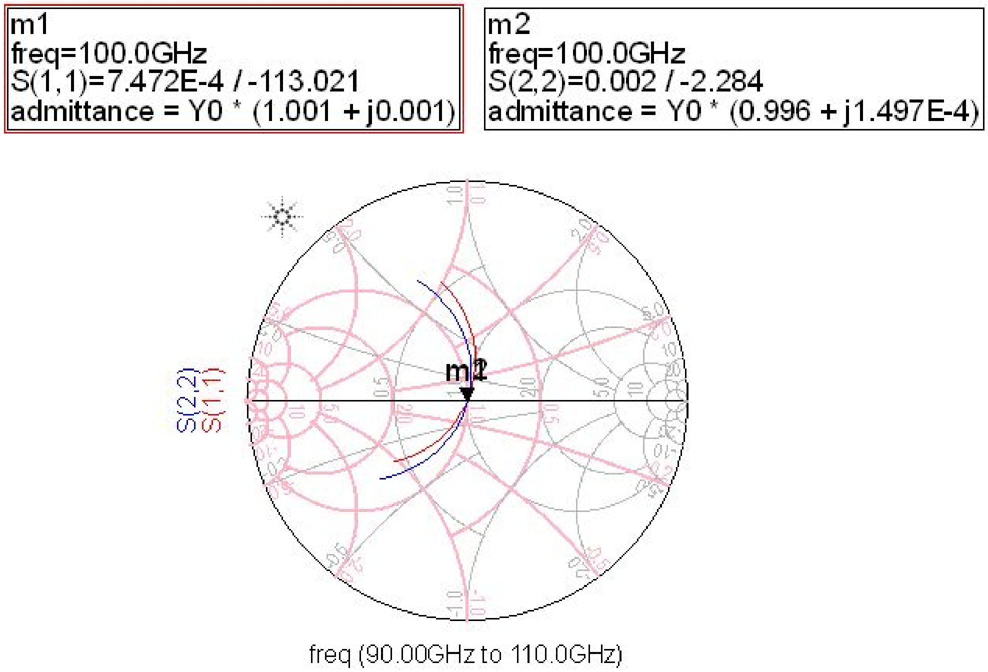
Tune to constant conductance:





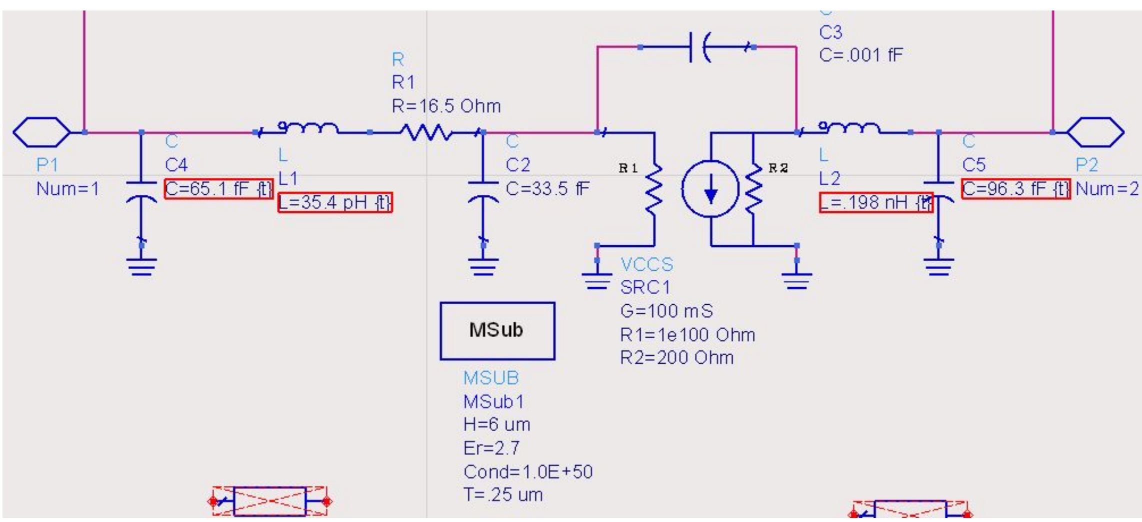
Adding shunt inductance to move along constant circle of conductance:



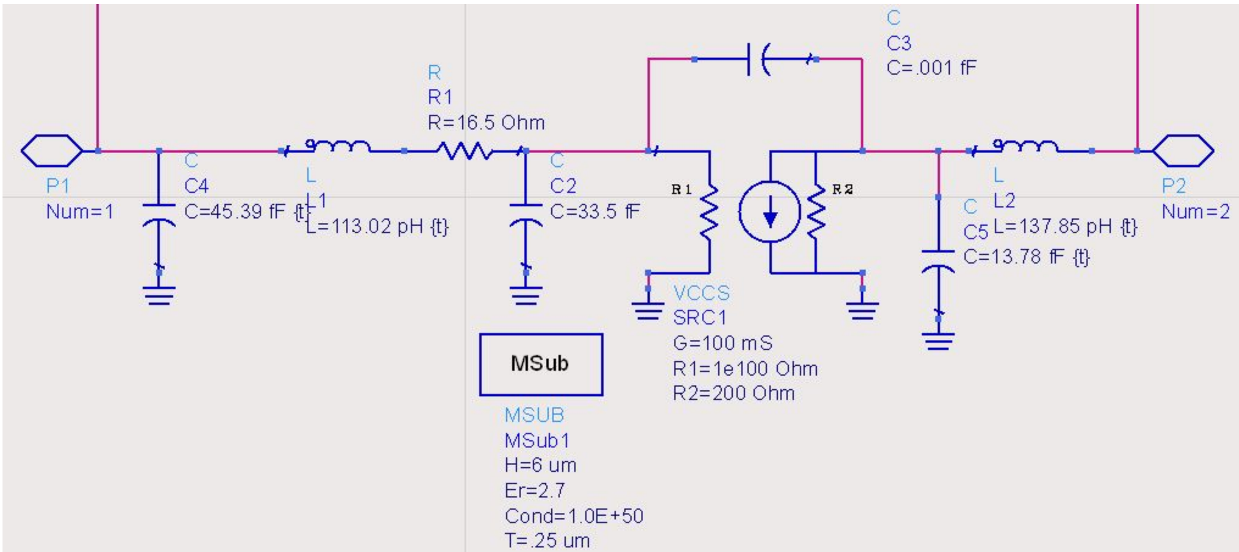


Part B

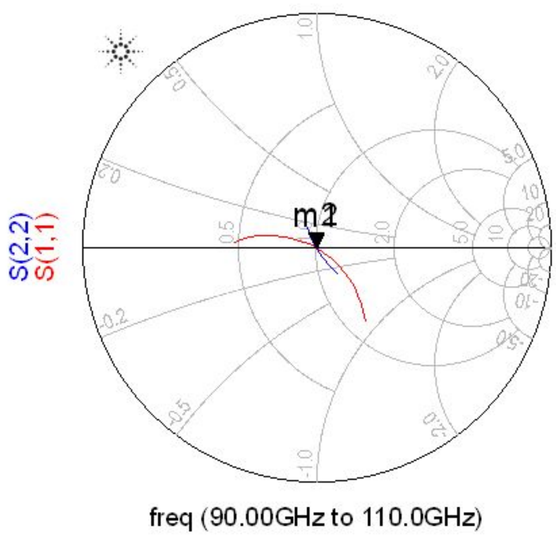
Initial Lumped RC Matching Circuit



Lumped RC Matching Circuit after tuning

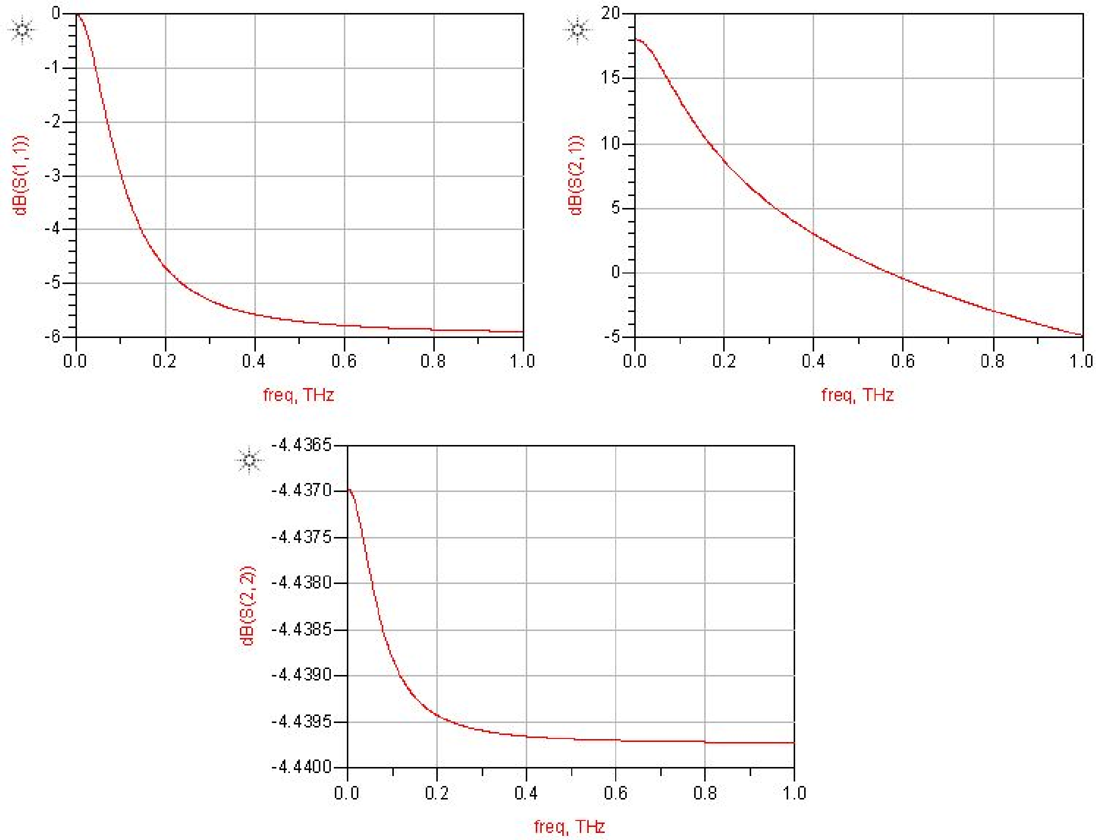


m1	m2
freq=100.0GHz	freq=100.0GHz
S(1,1)=6.754E-4 / -68.804	S(2,2)=5.253E-4 / 101.187
admittance = Y0 * (1.000 + j0.001)	impedance = Z0 * (1.000 + j0.001)

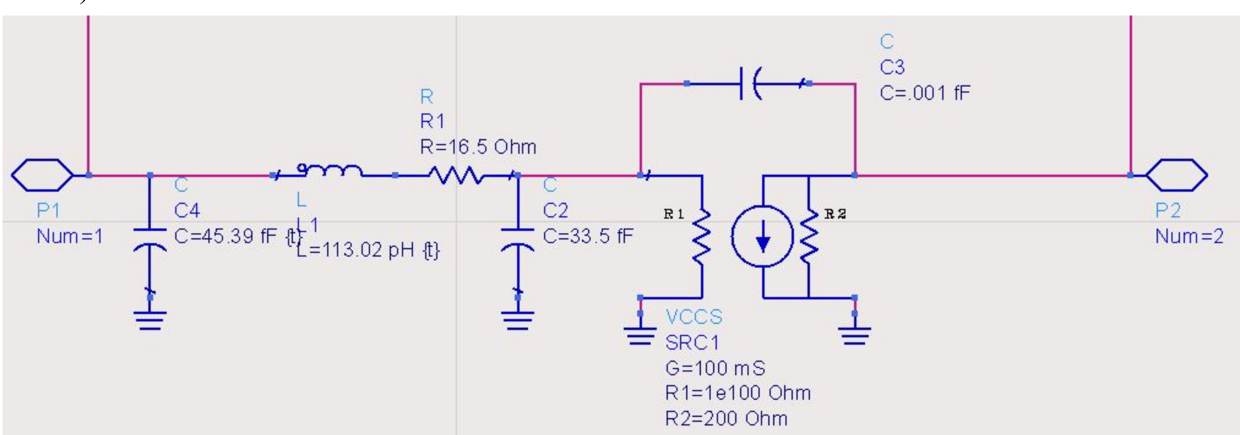


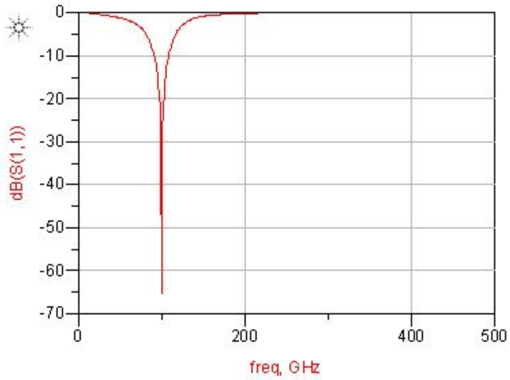
Problem 4

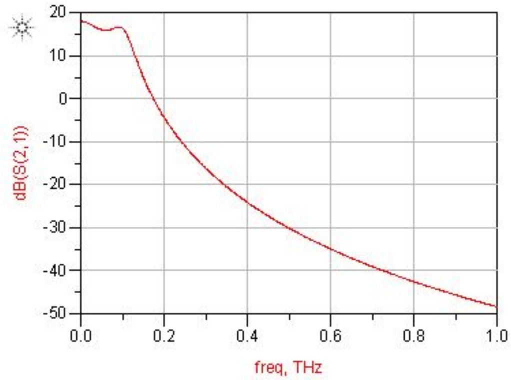
Part A)

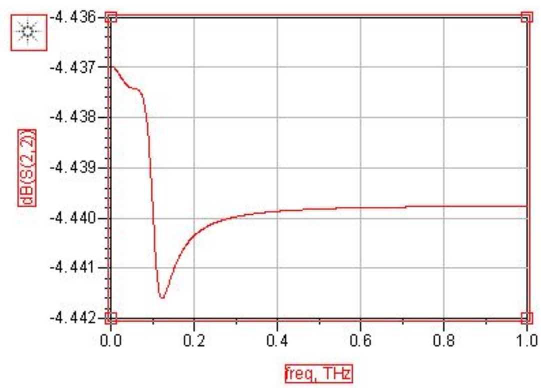


Part B)

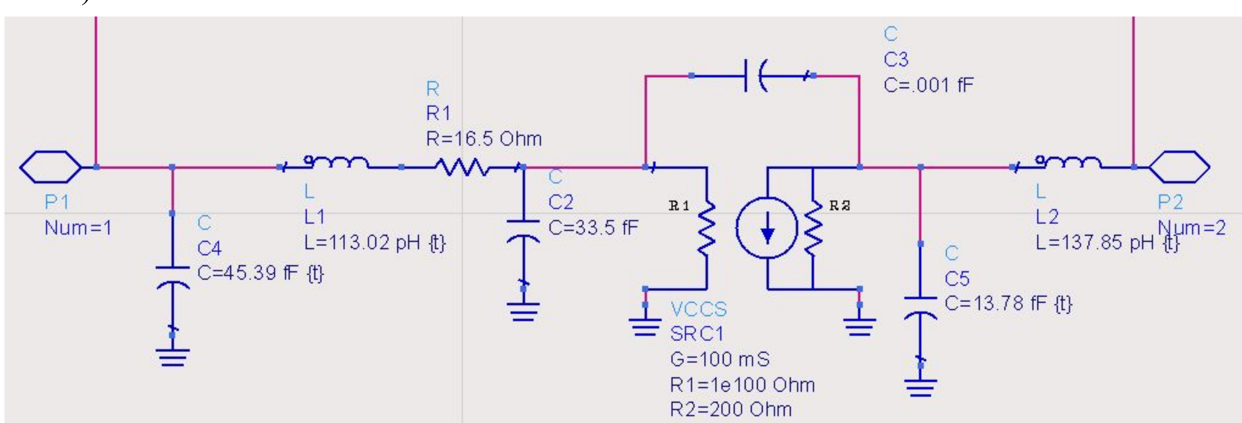


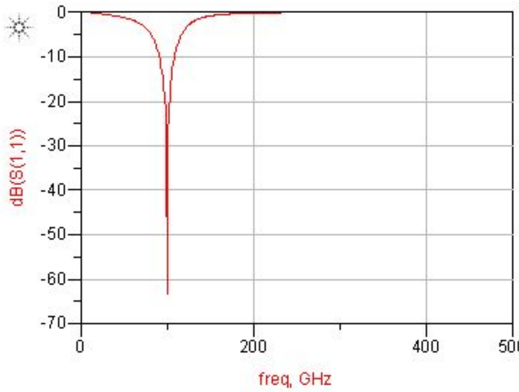

0
-10
-20
-30
-40
-50
-60
-70
dB(S(1,1))
0
200
400
500
freq, GHz

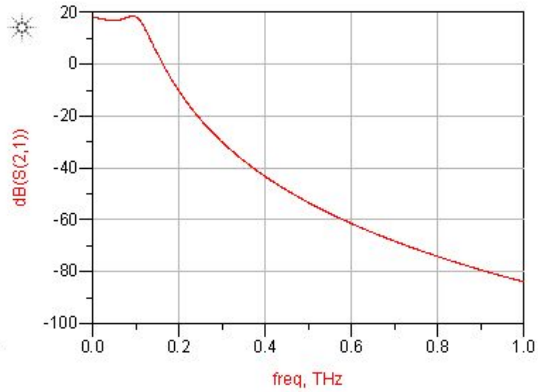

20
10
0
-10
-20
-30
-40
-50
dB(S(2,1))
0.0
0.2
0.4
0.6
0.8
1.0
freq, THz

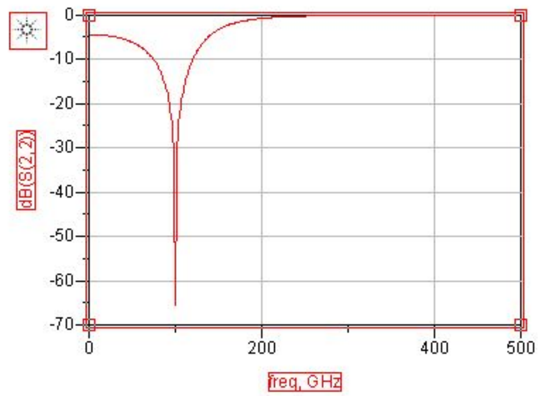

-4.436
-4.437
-4.438
-4.439
-4.440
-4.441
-4.442
dB(S(2,2))
0.0
0.2
0.4
0.6
0.8
1.0
freq, THz

Part C)


P1
Num=1
C
C4
C=45.39 fF {t}
L
L1
L=113.02 pH {t}
R
R1
R=16.5 Ohm
C
C2
C=33.5 fF
C
C3
C=.001 fF
R1
R2
VCCS
SRC1
G=100 mS
R1=1e100 Ohm
R2=200 Ohm
C
C5
C=13.78 fF {t}
L
L2
L=137.85 pH {t}
P2
Num=2

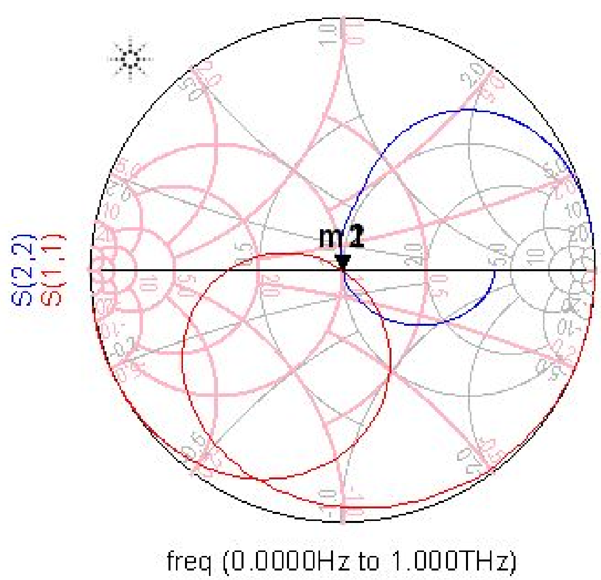






Part D)

m1	m2
freq=100.0GHz	freq=100.0GHz
S(1,1)=6.840E-4 / 46.714	S(2,2)=5.260E-4 / 108.216
admittance = Y0 * (0.999 - j9.950E-4	impedance = Z0 * (1.000 + j9.989E-4)

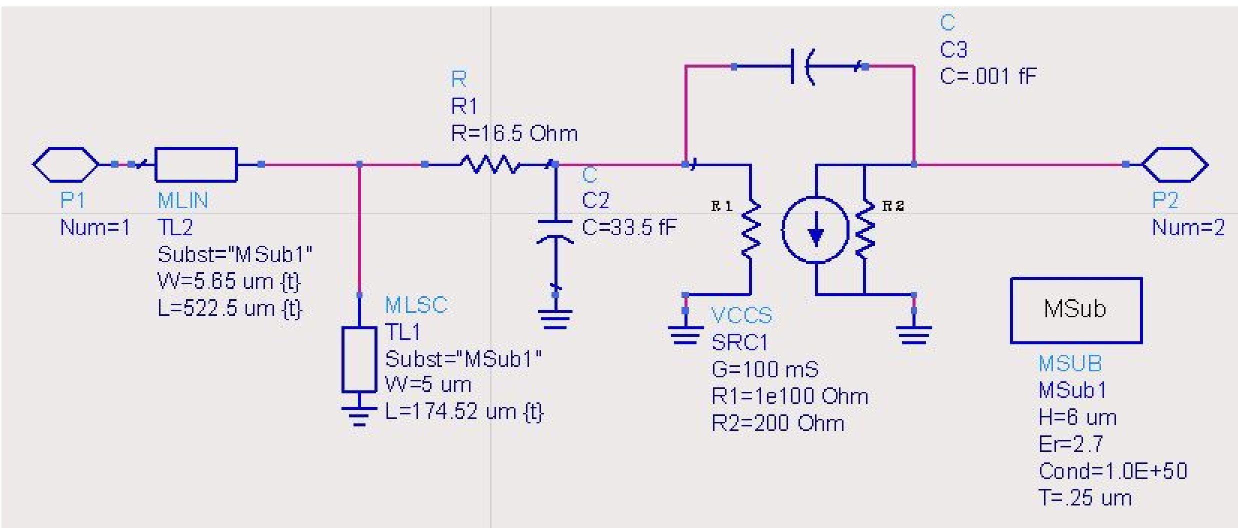


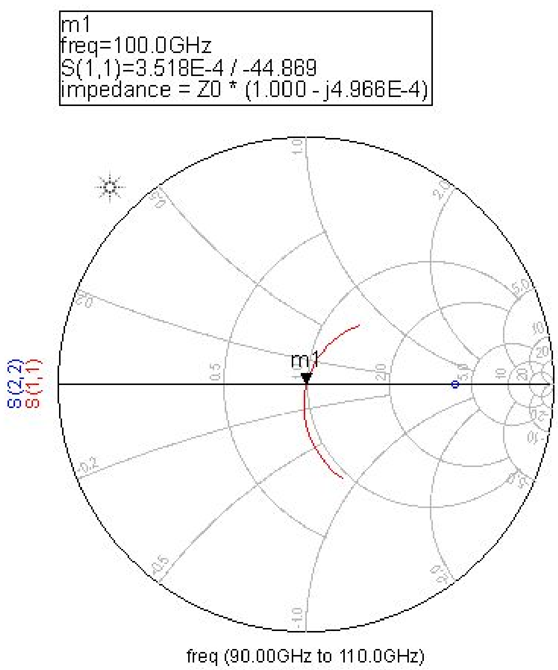
Tuning is more complicated now that S11 and S22 are dependent on each other.

Part E) It is impossible to match the circuits because the connections between the input and the output (Cgd) is too large. In other words, S11 and S22 are too dependent on each other to perfectly match the networks.

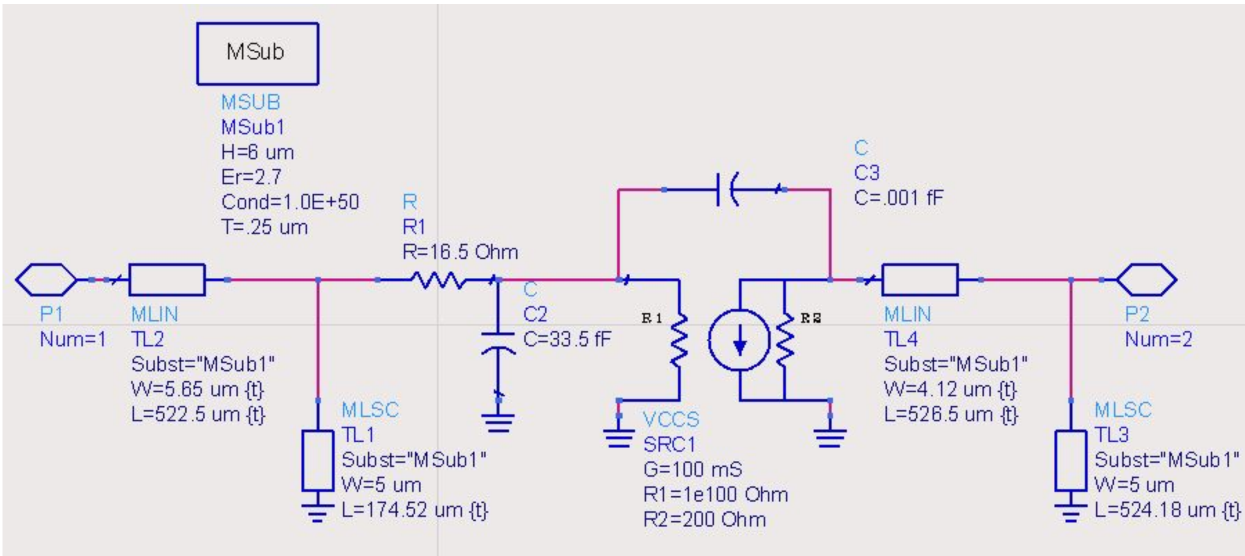
Problem 5

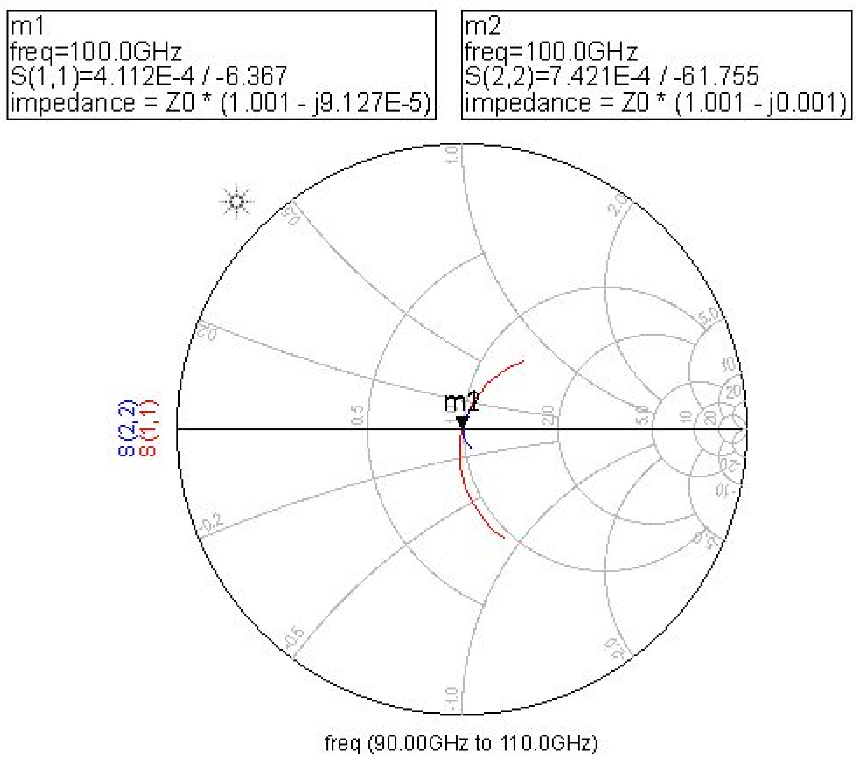
SC-High-Impedance-Shunt Stub and Series Line at Input



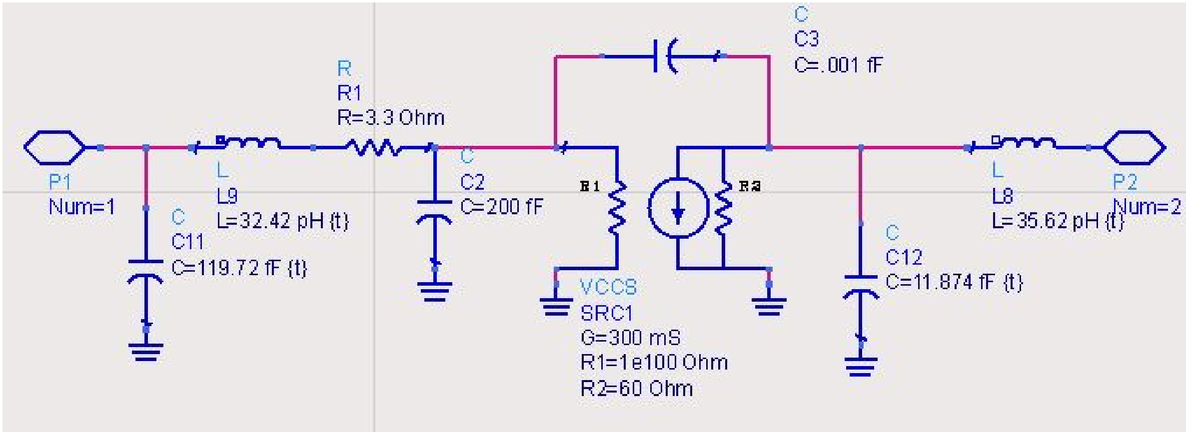


SC-High-Impedance-Shunt Stub and Series Line at Output

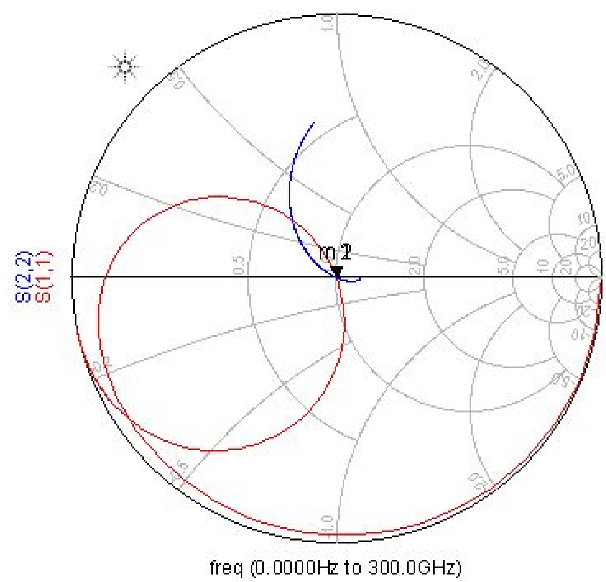




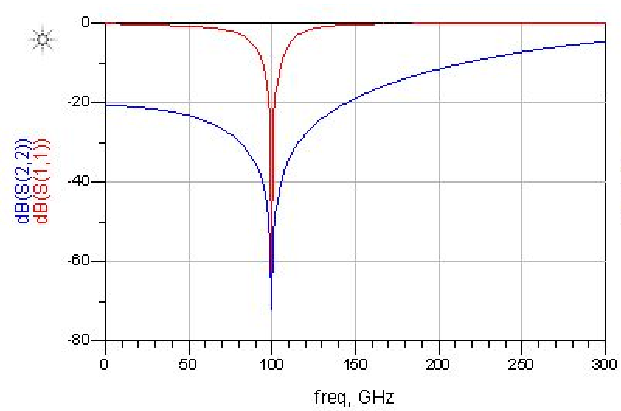
Problem 6

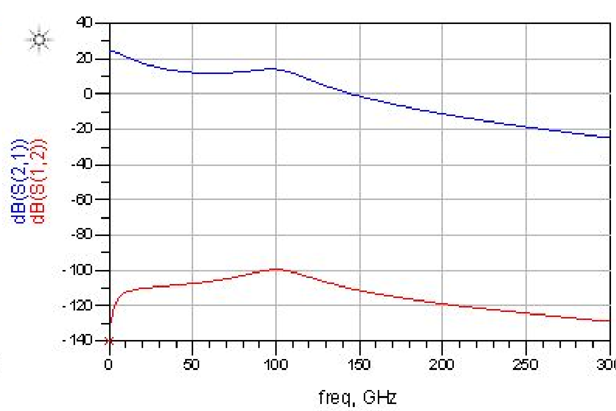


m1	m2
freq=100.0GHz	freq=100.0GHz
S(1,1)=5.570E-4 / 100.676	S(2,2)=2.470E-4 / 169.894
impedance = Z0 * (1.000 + j0.001)	impedance = Z0 * (1.000 + j8.663E-5)



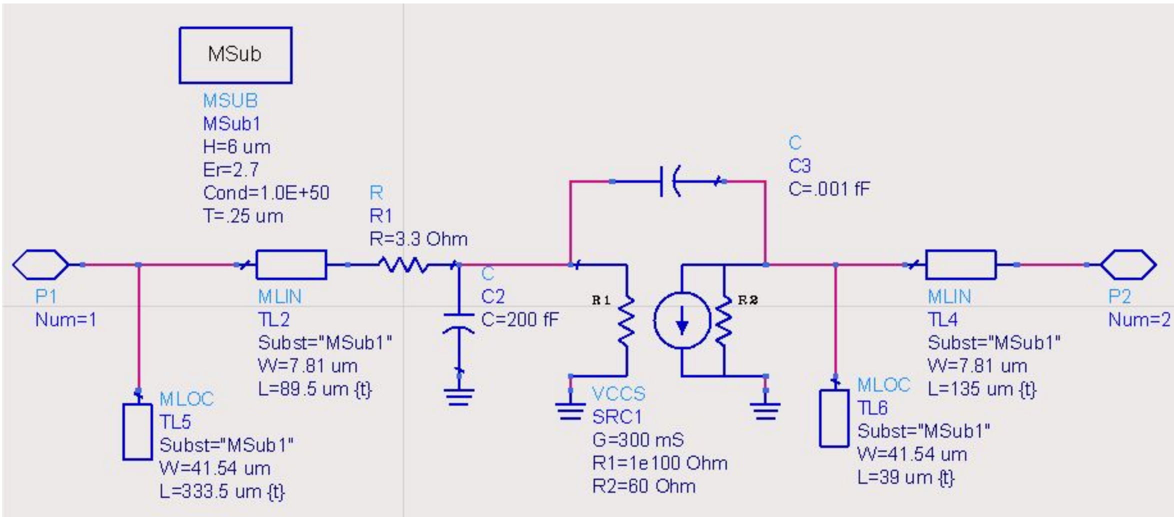
Part B

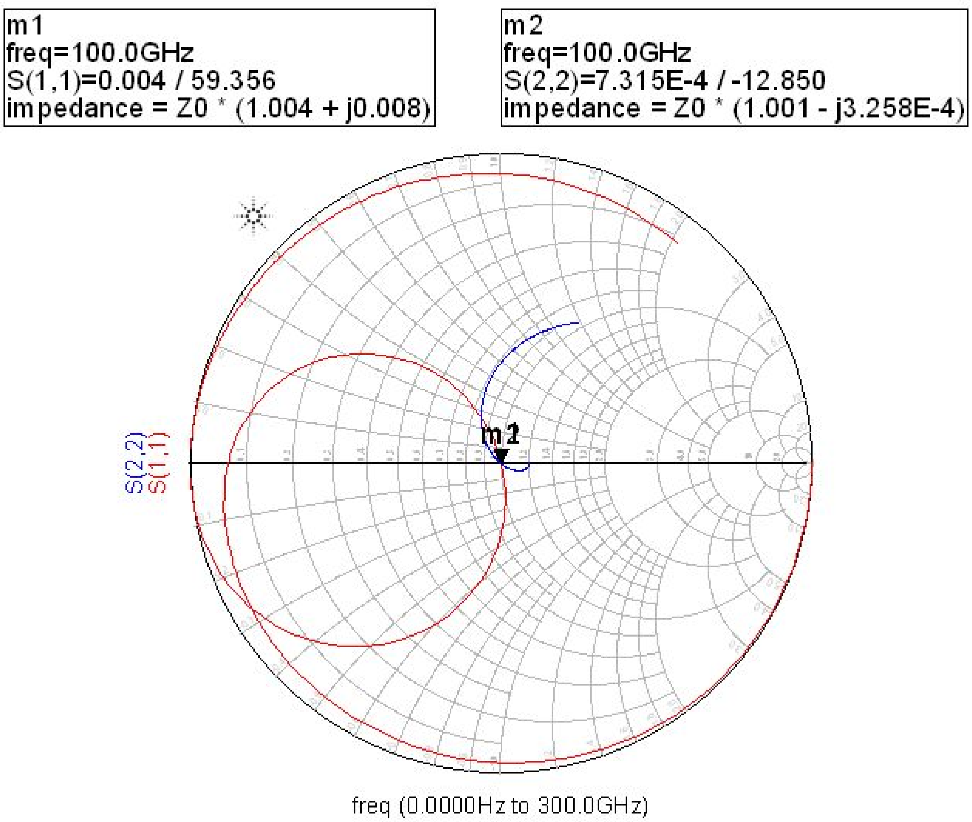




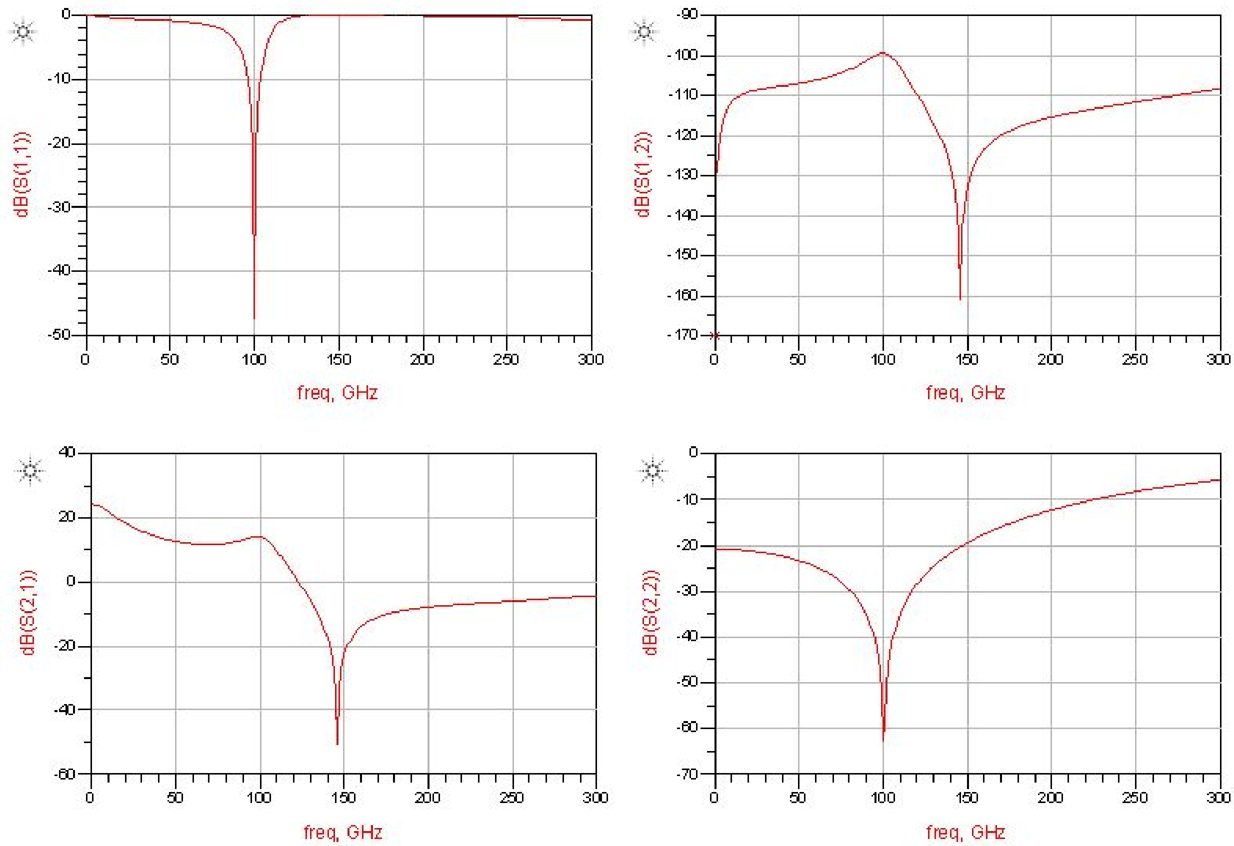
Problem 7

Part A

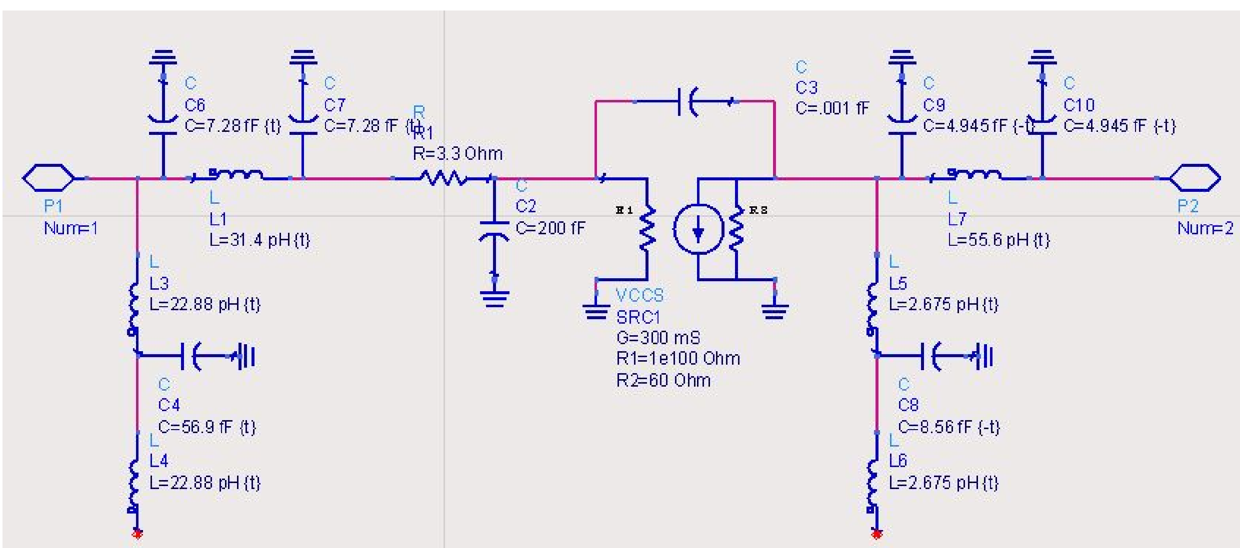


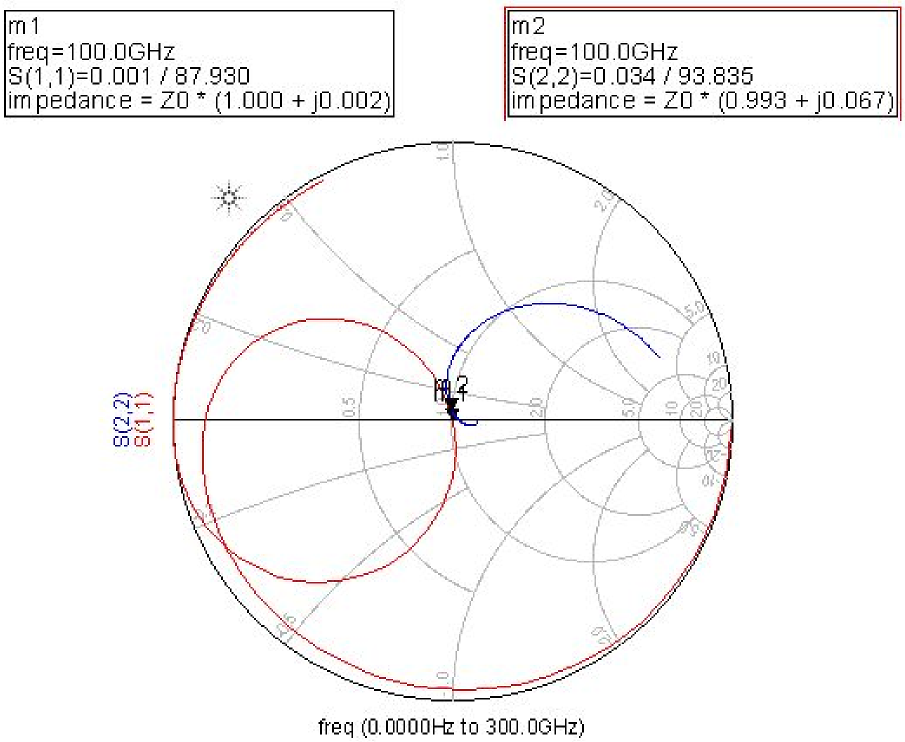


Part B

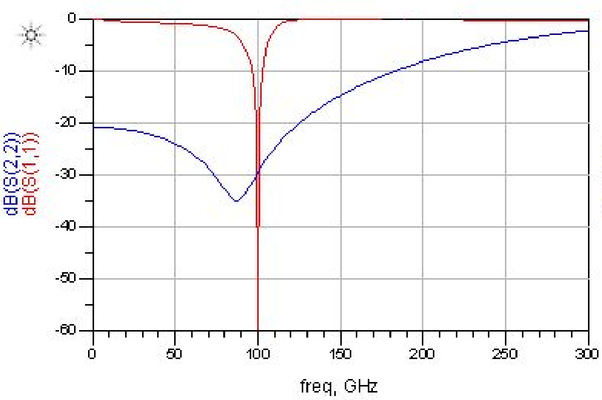


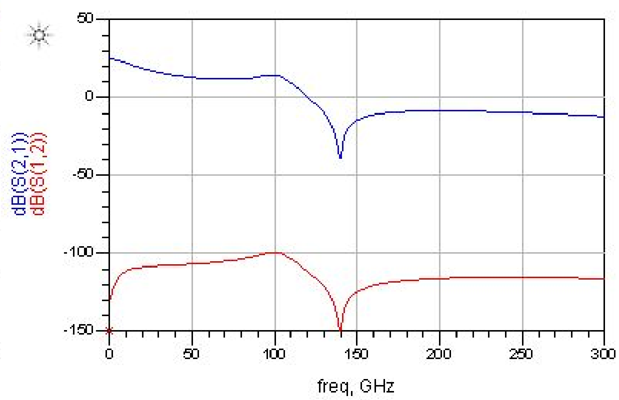
Problem 8





Part B)





Problem 9